CHAPTER 2

POWER TRAIN

The heart of the power train is the internal combustion engine that provides the power required to move a vehicle. However, this task is made much more efficient with the aid of the transmission and the other drive-line components that make up the power train (fig. 2-1). This chapter covers the basic principles of manual and automatic transmissions, propeller shaft assemblies, and final drives.

TRANSMISSIONS

Power from the engine provides the torque required for the transmission to overcome inertia. Inertia is a property of matter by which it remains at rest or in uniform motion in a straight line unless acted upon by some external force. In this case, the inertia of the vehicle at rest is overcome by an external force—the engine power in the form of torque. Once the vehicle is moving, acceleration begins and increases and very little torque is then required. The bigger the load on the engine, the bigger and more efficient the transmission must be. Once a vehicle gains the desired speed, it moves along with very little effort until something is encountered, such as a grade in the road, that increases the resistance to its movement. Now torque is required again and the operator has to select a lower gear.

The transmission (fig. 2-2) provides the mechanical advantage that enables the engine to move the vehicle. It allows the operator to control the power and speed of the vehicle and allows disengaging and reversing the flow of power from the engine to the wheels by means of a clutch.

CLUTCH

The clutch engages and disengages the engine crankshaft to or from the transmission and the rest of the power train. Engine power to the load must be applied slowly to allow a smooth engagement and to lessen shock on the driving and driven parts. After engagement, the clutch must transmit the engine power to the transmission without slipping. Additionally, the engine must be disconnected from the power train in order to shift gears.

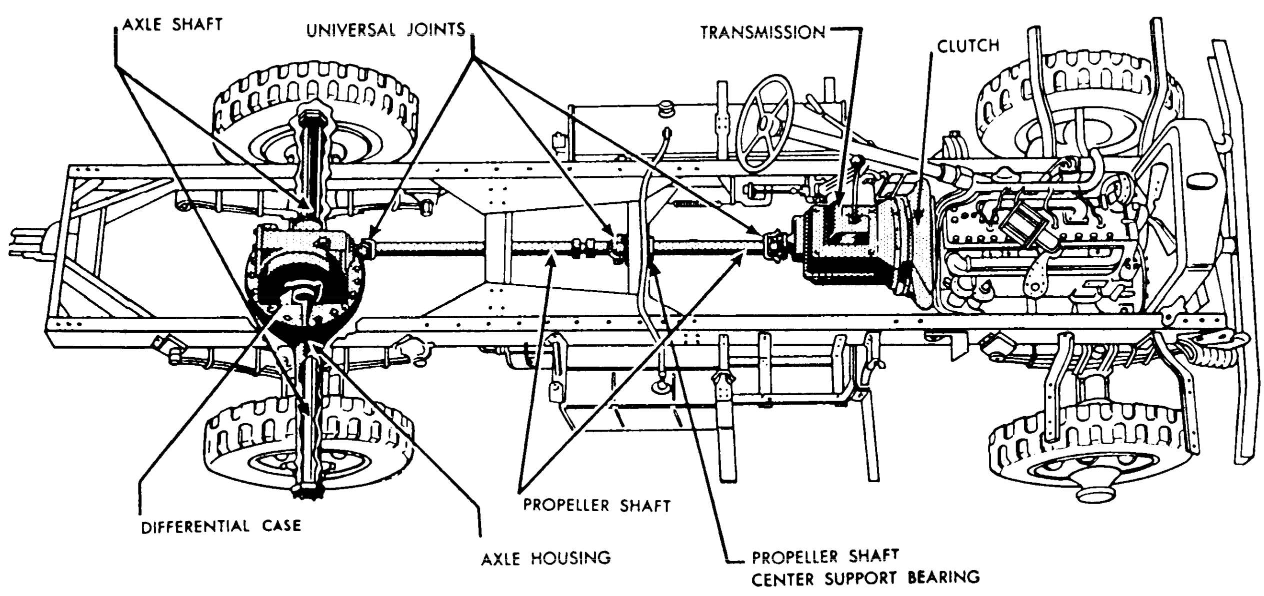

Figure 2-1.-Typical power train.

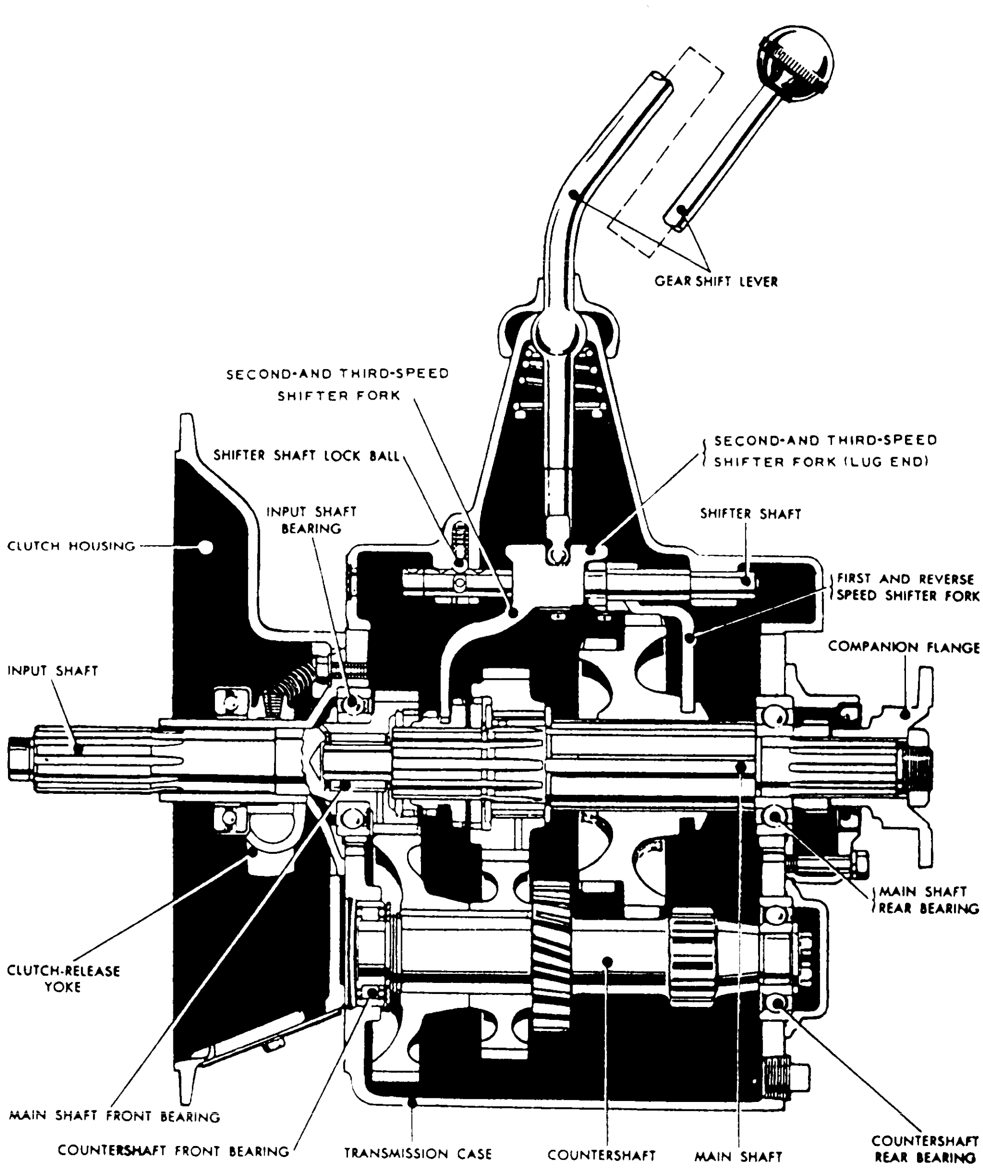

Figure 2-2.—Typical manual shift transmission.

Clutches transmit power from the clutch driving member to the driven member by friction. In the **DISC CLUTCH** (fig. 2-3), the driving plate secured to the engine flywheel gradually contacts the driven member (disc) attached to the transmission input shaft. The contact is made and held by strong spring pressure controlled by the operator with the clutch pedal (fig. 2-4). With only light spring pressure, there is little friction between the two members, and the clutch can slip; therefore, do not use the clutch pedal as a footrest. As the spring pressure increases, friction also increases, and less slippage occurs. When the operator's foot is removed from the clutch pedal and the full spring pressure is applied the speed of the driving plate and driven disc is the same and all slipping stops. The flywheel and the transmission input shaft are then connected.

Improper adjustment can damage or ruin a clutch. Figure 2-5 shows the proper free travel and linkage. Several clutch troubles may occur during vehicle operation that should be documented and turned in before too much damage occurs. These troubles include incorrect free travel, slipping, chattering, or grabbing when engaging; spinning or dragging when engaged; and clutch noises.

MANUAL TRANSMISSION

The transmission is located at the rear of the engine between the clutch housing and the propeller shaft. The

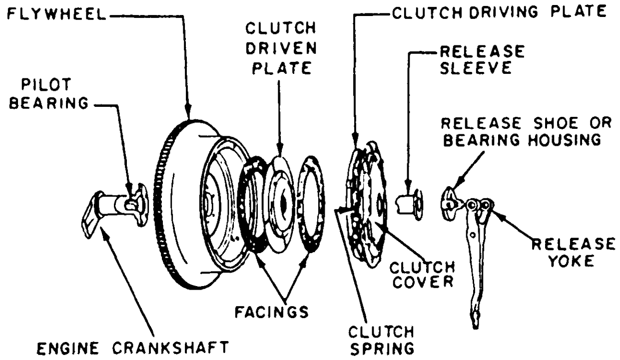

Figure 2-3.-Cross section of a disc clutch.

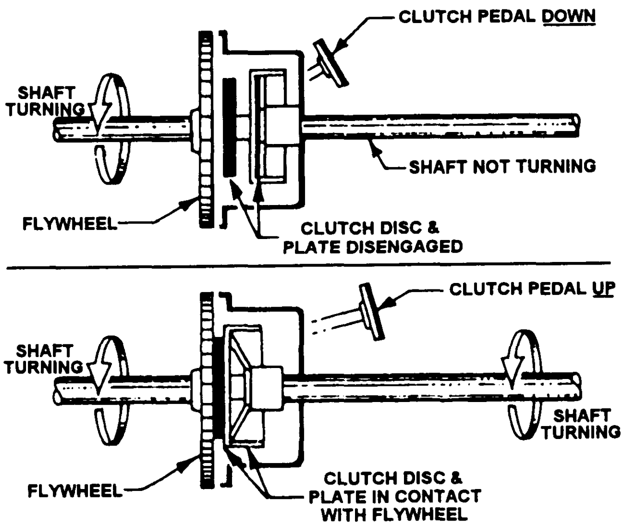

Figure 2-4.-Disc clutch operation.

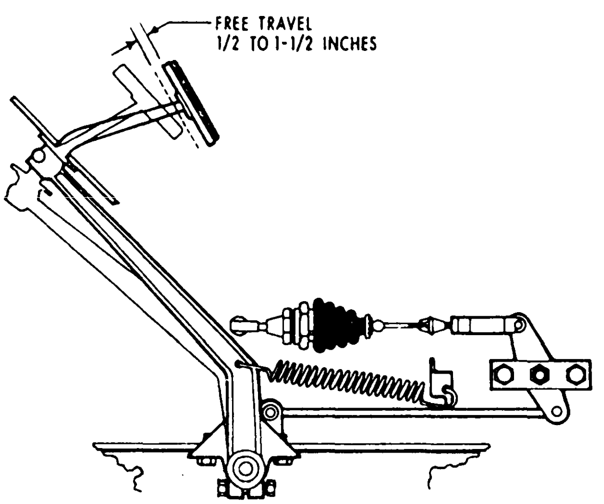

Figure 2-5.-Clutch linkage.

transmission transfers engine power from the clutch shaft to the propeller shaft and allows the operator to change the gear ratio between the engine and the rear wheels.

Dual-ratio, or two-speed rear axles are often used on trucks. They have two gear ratios that can be chosen by the operator, usually by a manual control lever. A dual-ratio rear axle works the same as the auxiliary transmission; it doubles the number of gear ratios for driving the vehicle under the various loads and on different roads.

The most common transmission type is the synchromesh transmission. The synchromesh transmission is basically a constant mesh, collar-shift transmission with an extra device, called a synchronizer, to equalize the speed of the mating parts before they engage. The synchronizer is used in all manual automotive transmissions and is common in other equipment where shifting while moving is required.

Part of the prestart operation is to check the fluid level in the manual transmission. The normal level of lubricant is usually at the bottom of the filler plug opening. When lubricant is needed, you should always check the operator's manual for the location and type of lubricant required for the transmission. When you keep the lubricant level correct, the gear teeth are protected, foam is reduced, and the transmission runs smoothly.

Some transmission troubles that you may encounter and must document are as follows:

- Hard shifting
- Slipping out of gear
- No power through the transmission
- Transmission noisy when in gear
- Gear clash in shifting
- Oil leaks

Manual Shift Operation

Skill in manual shifting is a requirement of professional driving. Poor manual shifting results in poor vehicle performance and can cause vehicle damage. Know the gearshift lever positions so well that you can shift to any gear without looking at the shift lever. The gearshift pattern is usually diagramed in the vehicle or in the operator's manual. Never move the gearshift lever from one position to another while the engine is running until you have fully depressed the clutch pedal with your left foot. To shift gears smoothly and quietly, you must keep the pedal fully depressed until the shift has been completed.

You should understand that the clutch provides the means of applying engine power to the wheels smoothly and gradually. To be a professional operator, you must learn just where the clutch starts to engage, how far the pedal must move to become fully engaged how much free play there is in the pedal, and how fast you should engage the clutch.

Keep your foot off the clutch pedal except when actually starting, stopping, or shifting gears. Even the slight constant pressure on the clutch pedal causes excessive wear. For the same reason, when stopped on a hill, never slip your clutch to keep from rolling backward; instead, use the brakes. Depress the clutch pedal and shift the transmission shift lever into neutral while waiting for a long traffic light or when halted for other reasons. Release the clutch after shifting into neutral.

When slowing your vehicle to stop or make a turn, be sure to reduce the vehicle speed to 15 miles per hour or less before depressing the clutch pedal. Coasting a vehicle at a high rate of speed with the clutch pedal depressed is dangerous, because control becomes more difficult and damage to the clutch may occur. This kind of practice is abusive to the vehicle.

CLUTCH SHIFTING.— After the prestart operation has been performed and you have acquainted yourself with the instruments and controls of the vehicle, warm the engine with the transmission in neutral. Start the vehicle moving with the transmission in low or first gear by following these steps:

1. Depress the clutch pedal and shift into low gear.

2. Check the mirrors, check blind spots, and give signals as required.

3. Let the clutch pedal up slowly, pausing at the friction point or when you feel it taking hold. Again, recheck the mirrors for traffic.

4. Release the parking brake and slowly release the clutch pedal, and at the same time, slightly depress the accelerator.

5. When the driving operation is under way, remove your left foot completely from the clutch pedal.

DOUBLE-CLUTCH SHIFTING.— Professional driving practice in trucks (1 1/2 ton or larger) often requires double clutching to permit proper engagement of the gears and to prevent loss of momentum. To shift to a lower gear by double clutching, follow these steps:

1. Release the pressure from the accelerator as you begin depressing the clutch pedal.

2. When the clutch pedal is fully depressed, move the gearshift lever to neutral position

3. Release the clutch pedal, and at the same time, depress the accelerator to speed up the engine.

4. Letup on the accelerator and depress the clutch pedal.

5. While the pedal is depressed move the gearshift lever to the next lower gear.

6. Release the clutch pedal, and at the same time, depress the accelerator to maintain engine speed as the load is again connected to the engine by the engagement of the clutch.

The procedure is the same for shifting to a higher gear speed, except that the engine is *NOT accelerated* while the transmission is in neutral.

CAUTION

When you are shifting gears in rough terrain and on hills, never let your vehicle slow down to a point where the engine begins to labor or jerk before shifting into a lower gear ratio. Always anticipate the need for extra power and shift gears accordingly. When descending a hill, with or without a heavy cargo load, always drive with your vehicle in gear and the clutch pedal out.

NOTE: You may encounter vehicles that may have more complicated transmissions, such as multigear ranges, dual-speed axles, or other special features. As an operator, read and understand the operator's manual pertaining to a particular vehicle before attempting to operate it.

AUTOMATIC TRANSMISSION

The automatic transmission, like the manual transmission, is designed to match the load requirements of the vehicle to the power and speed range of the engine. However, the automatic transmission (fig. 2-6) performs this automatically, depending on the throttle position, vehicle Speed, and position of the shift control lever. Automatic transmissions are manufactured in models that have two, three, four, or more forward

2-8speeds and some are equipped with overdrive. Operator control is limited to the selection of the gear range by moving a control lever.

Part of the prestart operation is to check the transmission fluid level when the engine is idling and at normal operating temperature, when the vehicle is level, and when the transmission control lever is in park. The transmission fluid is used as a combination power transmission medium, hydraulic control fluid, heat transfer medium, bearing surface lubricant, and gear lubricant. The manufacturer's recomendations must be followed when servicing and filling the transmission with fluid.

CAUTION

Do not overfill the transmission because overfilling causes foaming and shifting troubles.

Some transmission troubles you may encounter and must document are as follows:

- No drive in any selected positions.
- On standstill starts the engine speed accelerates but the vehicle movement lags.
- Engine speed accelerates during upshifts.
- Transmission will not upshift.
- Upshift and downshift are harsh.
- Vehicle creeps too much in drive.
- Vehicle creeps in neutral.
- Improper shift points.
- Unusual transmission noise.
- Oil leaks.

Fluid Couplings

In the past, fluid couplings were widely used with automatic transmissions. Fluid couplings act like an automatic clutch by slipping at idling speeds and by holding to increase power as the engine speed increases. There is no mechanical connection between the engine and transmission; power is transmitted by oil.

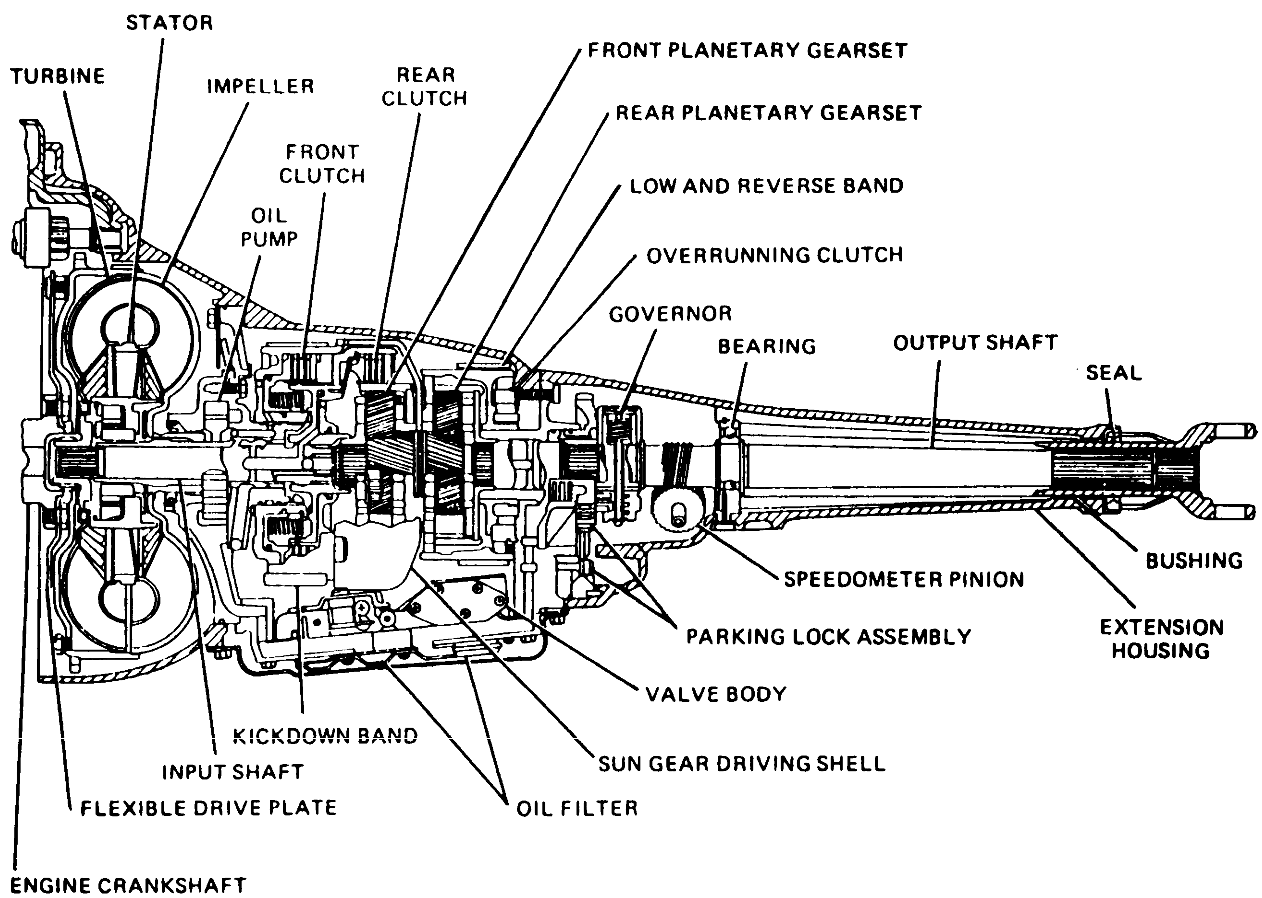

Figure 2-6.—Automatic transmission cross-sectional view.

The principle of fluid drive is shown in figure 2-7. As two fans face each other, the speed of rotation of one fan makes the other fan rotate. When the speed of one fan is changed from medium to low, power is lost at low speeds; but, if the fan speed increases from medium to high, the speed of the driven fan picks up.

Torque Converter

The torque converter is a form of and has replaced the fluid coupling. Most automatic transmissions used in automotive and construction equipment have torque converters.

The torque converter consists of three parts: the pump (driving member), the turbine (driven member), and the stator (reaction member), all with curved vanes. The stator is located between the load and the power source to act as a fulcrum and is secured to the torque converter housing. Figure 2-8 shows a cutaway view of a torque converter and the directional flow of oil. The pump throws out oil in the same direction in which the pump is turning. As the oil strikes the turbine blade, it forces the turbine to rotate, and the oil is directed toward the center of the turbine. Then the oil leaves the turbine and moves in a direction opposite to that of the pump. As the oil strikes the stator, it is redirected to flow in the same direction as the pump to add its force to that of the pump. Torque is multiplied by the velocity and direction given to the oil by the pump, plus the velocity and direction of the oil entering the pump from the stator.

Planetary Gears

Automatic transmissions use a system of planetary gears to enable the torque from the torque converter to be used efficiently.

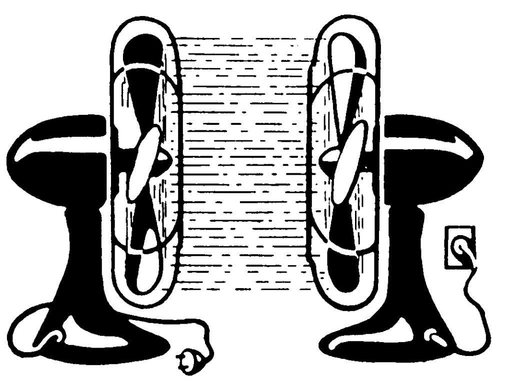

Figure 2-7.—Principle of fluid drive.

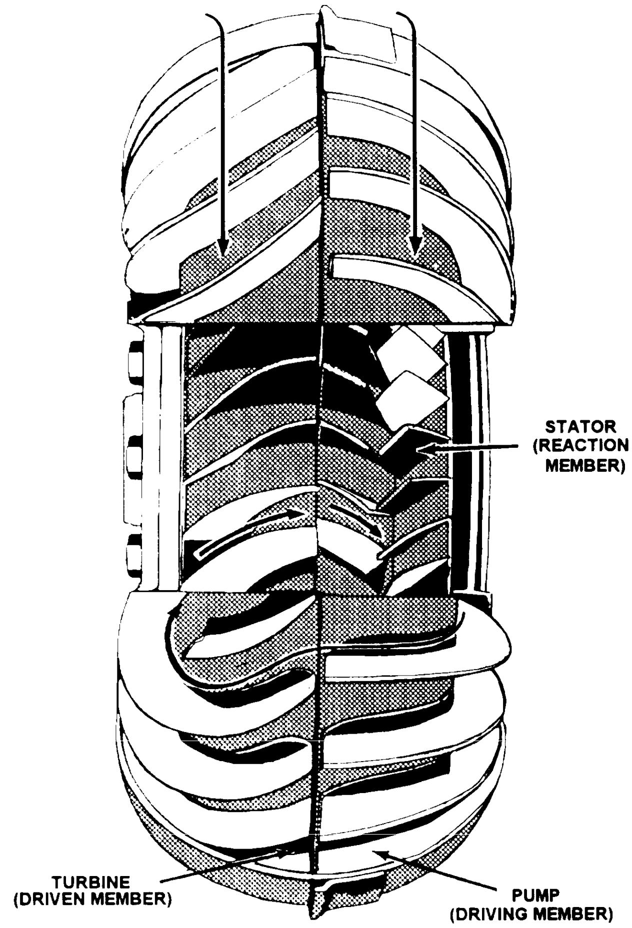

Figure 2-8.—Torque converter.

Planetary units are the heart of the automatic transmission. The four parts that make up the planetary gear system are as follows: the sun gear, the ring (or internal) gear, the planet pinions, and the planet carrier.

The sun gear is the center of the system. The term **planet** fits these pinions and gears, because they rotate around the sun gear, as shown in figure 2-9. The ring gear, or internal gear, is so-called because of its shape and internal teeth.

An advantage of the planetary gear system is that it is compact. Additionally, in the planetary system more teeth make contact to carry the load. The reason for this is that each gear of the planetary system usually meshes with at least two other gears. Because the gears are always in mesh, none of the teeth are damaged as a result of teeth clashing or a partial mesh. However, the major advantage of the planetary system is the ease of shifting gears. Planetary gears, set in automatic transmissions, are shifted without any special skill required by the operator.

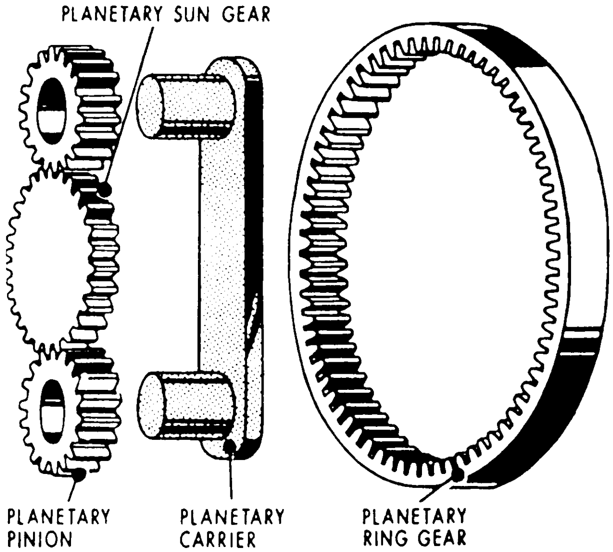

Figure 2-9.—Planetary gear system.

Power can be transmitted through the planetary gearset in various ways. A shaft from the engine may be connected to drive the sun gear. It may be connected to drive the planet carrier or the shaft may be connected to drive the ring gear. The propeller shaft may also be connected to anyone of these members; however, power can be transmitted in the planetary gear system only when (1) the engine is delivering power to one of the three members, (2) the propeller shaft is connected to one of the other members, and (3) the remaining member is held against rotation. All three conditions must be satisfied for power to be transmitted in the system. Automatic transmissions provide for holding a member through hydraulic servos and spring pressure.

Automatic Transmission Operation

Most automatic transmissions are basically the same. They combine a fluid torque converter with a planetary gearset and control the shifting of the planetary gear with an automatic hydraulic control system. The fluid torque converter is attached to the engine crankshaft and serves as the engine flywheel. This design means that when the engine runs, engine power flows into the converter and drives the converter output (turbine) shaft. There is no neutral in the torque converter. Neutral is provided in the planetary gearset by the release of bands and clutches.

The transmission automatically multiplies and transmits engine torque to the drive shaft as driving conditions demand. The speeds at which the coupling point and the gearshifts occur are controlled partially by the operator. The operator has only a partial control in the D-drive position, because the transmission in the D-drive position shifts the planetary gearset into the higher gears to prevent engine overspeeding regardless of throttle position.

The operation of automatic shift vehicles is quite simple; however, it is imperative that the professional operator learn to operate them smoothly and properly. In vehicles equipped with automatic transmissions, initial gear selection is controlled with a selector lever. When in drive (D or DR), shifting from drive to low (L) and returning to drive is controlled automatically by the engine speed.

Most vehicles have four or five of the following selector positions.

P-PARK POSITION.— On light vehicles, such as sedans and pickups, this position is used for locking the transmission so the vehicle cannot roll while parked. In some heavier vehicles, the park position does not lock the transmission. In vehicles with a park position, the engine should be started from the park position.

N-NEUTRAL POSITION.— Engines of vehicles not equipped with a P-park position are started from the N-neutral position. In this position, the engine is disengaged from the drive shaft of the vehicle.

D-DRIVE POSITION.—With the shift lever at D or DR, the vehicle moves forward as you depress the accelerator. After starting the engine in neutral or park position, step on the brake and change the selector to D or DR for forward movement. To avoid premature forward movement, keep pressure on the brake while in the drive position until you are ready to place the vehicle in motion. Without further operator action, the transmission automatically shifts to higher gears as speed increases.

L-LOW or POWER POSITION.— The transmission will not shift automatically to higher gear ratios when the lever is in the low position. The low position is used when negotiating steep grades and rough terrain or when the braking power of the engine is required. When low range is no longer needed, release the accelerator temporarily and move the shift lever to the drive position for normal gear progression. In the drive position, the low range is engaged automatically when engine speed is reduced. If the accelerator is suddenly fully depressed, the low range becomes engaged. (This procedure may be used to provide a sudden burst of speed for passing.) When a predetermined engine speed has been attained, the transmission automatically returns to driving range.

R-REVERSE POSITION.— Some shift levers must be raised slightly to be moved to the R or reverse position. Others may require the depressing of a button on the end of the lever before moving to R.

Become thoroughly familiar with the operator's manual, vehicle instruments, controls, and selector positions before operating a vehicle or piece of equipment. You may operate equipment that has the R-reverse position on the extreme right on some shift selectors, on the extreme left on others, and the intermediate position on others. From a force of habit, when you are in a different vehicle from the one you have been operating, you could move the selector lever to R, thinking you were moving it to D or L, and cause the vehicle to move in an entirely opposite direction than anticipated.

AUXILIARY TRANSMISSION

Auxiliary transmissions are mounted on the rear of the regular transmission to provide more gear ratios. Most auxiliary transmissions have only a L-low and a H-high (direct) range in a transfer assembly. The low range provides an extremely low gear ratio for hard pulls. At all other times, the high range should be used. Gears are shifted by a separate gearshift lever in the driver's cab (fig. 2-10).

Transfer Cases

Transfer cases are placed in the power trains of vehicles driven by all wheels (fig. 2-11). Their purpose is to provide the necessary offsets for additional propeller-shaft connections to drive the wheels.

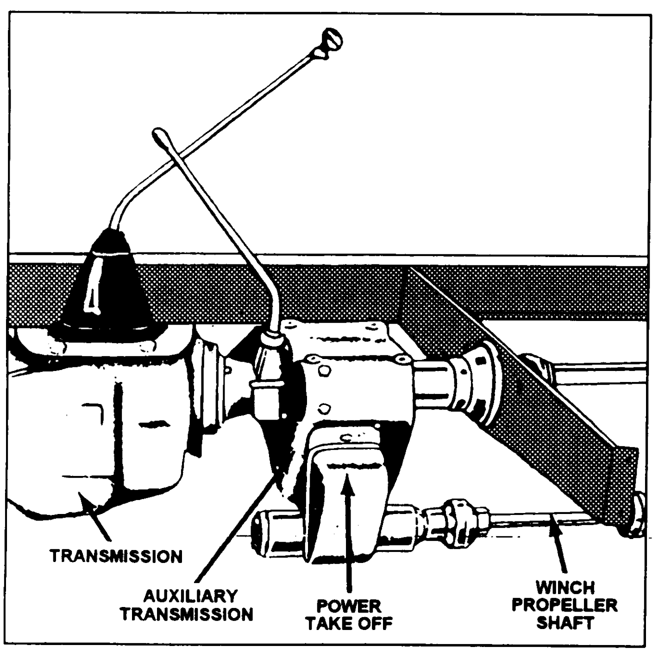

Figure 2-10.—Auxiliary transmission.

Transfer cases in heavier vehicles have two-speed positions and a declutching device for disconnecting the front driving wheels. Two-speed transfer cases also serve as auxiliary transmissions.

Transfer cases are quite complicated. When they have speed-changing gears, declutching devices, and attachments for three or more propeller shafts, they are even larger than the main transmission.

Some transfer cases have an overrunning sprag unit (or units) on the front output shaft. A sprag unit is a form of a overrunning clutch; power can be transmitted through it in one direction but not in the other. During normal operation, when both front and rear wheels turn at the same speed, only the rear wheels drive the vehicle.

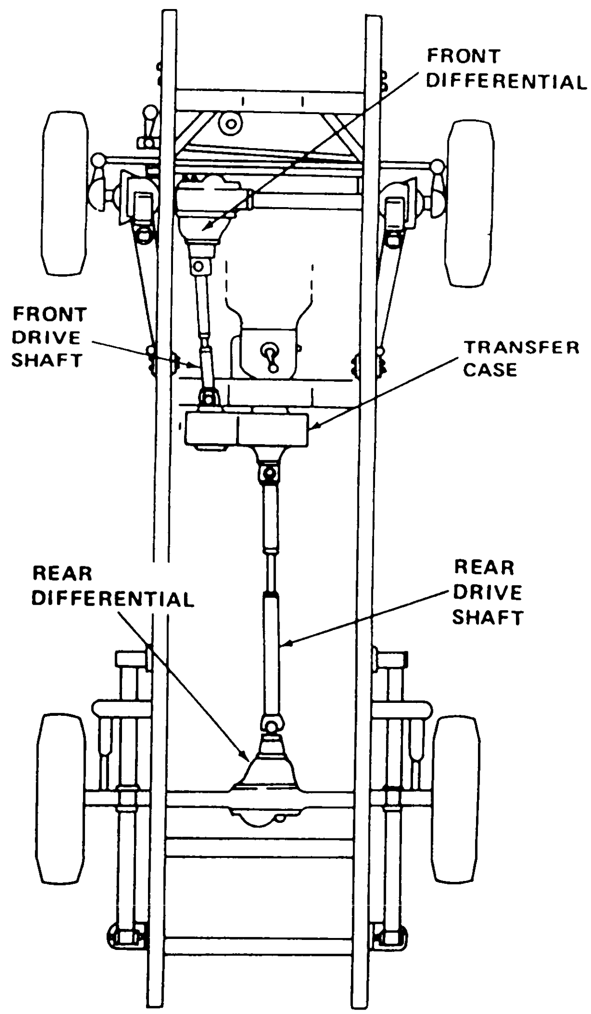

Figure 2-11.—Transfer case installed in a four-wheel drive truck.

However, if the rear wheels should lose traction and begin to slip, they tend to turn faster than the front wheels. When this occurs, the sprag unit automatically engages. This action allows the front wheels to also drive the vehicle. The sprag unit simply provides an automatic means of engaging the front wheels in drive for more traction.

Power Takeoffs

Power takeoffs, commonly known as the PTO, are attachments in the power train for power to drive auxiliary accessories. They are attached to the transmission, auxiliary transmission, or transfer case. A common type of PTO is the single-gear, single-speed type that is bolted to an opening provided in the side of the transmission case, as shown in figure 2-10. The sliding gear of the PTO meshes with the transmission countershaft gear. The operator can move a shifter shaft control lever to slide the gear in and out of mesh with the countershaft gear. The spring-loaded ball holds the shifter shaft in position.

On some vehicles, PTO units have gear arrangements that give two speeds forward and one in reverse. Several forward speeds and reverse gear arrangements are usually provided in PTO units used to operate winches and hoists.

PROPELLER SHAFT ASSEMBLIES

The propeller shaft assembly (fig. 2-12) consists of a propeller shaft, commonly know as the drive shaft, a slip joint, and two or more universal joints. This assembly provides a path through which power is transmitted from the transmission to the drive axle assemblies or auxiliary equipment. Vehicles, having a long wheel base, are equipped with a propeller shaft that extends from the transmission or transfer case to a center support bearing and a propeller shaft that extends from the center support bearing to the rear axle (fig. 2-13).

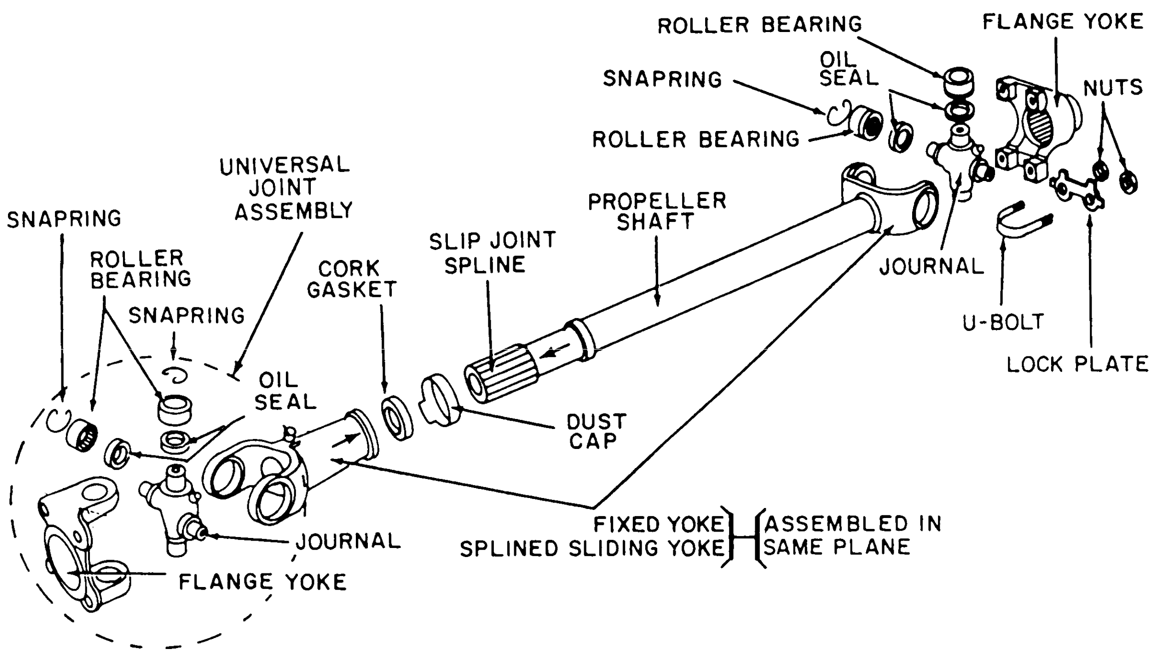

Figure 2-12.—Propeller shaft assembly.

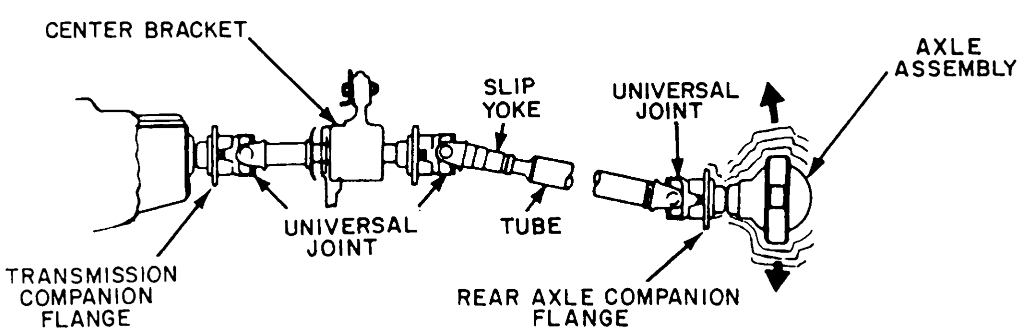

Figure 2-13.—Propeller shaft assembly with center support bearing.

Propeller shafts may be solid or tubular type and require little or no maintenance. Solid shafts are normally used where high shaft speeds are unnecessary. They are used extensively to power auxiliary equipment, such as winches and hydraulic pumps. The hollow shaft is used almost exclusively to transmit power to the axles on automotive vehicles. The hollow shaft, because it rotates at high speed, must be balanced to prevent vibration and premature bearing failure in the transmission and differential assemblies.

A slip joint at one end of the propeller shaft takes care of end play. The driving axle, attached to the springs, is free to move up and down, while the transmission is attached to the frame and cannot move. Any upward or downward movements of the axle causes the suspension springs to flex. This action shortens or lengthens the distance between the axle assembly and the transmission. The slip joint makes up for this changing vertical distance.

The type of slip joint normally used consists of a splined stub shaft, welded to the propeller shaft, that fits into a splined sleeve in the universal joint, as shown in figure 2-12.

UNIVERSAL JOINTS

A universal joint acts as a flexible coupling between two shafts and permits one shaft to drive another shaft that is at an angle to it. The universal joint is flexible in the sense that it permits power to be transmitted, while the angle of the shaft is being continually changed.

A conventional universal joint assembly is composed of three fundamental units: a journal (cross) and two yokes, as shown in figure 2-12. The two yokes are set at right angles to each other and are joined by the journal. This design permits each yoke to pivot on the journal, allowing the transmission of rotary motion from one yoke to the other. As a result, the universal joint can transmit power from the engine through the shaft to the drive axle, even when the engine is mounted in the frame at a higher level than the drive axle, as shown in figure 2-13.

Universal joints need little, if any, maintenance other than lubrication. Some universal joints have grease fittings and should be lubricated according to the manufacturer's specifications.

CENTER SUPPORT BEARINGS

When two or more propeller shafts are connected together in tandem, their alignment is maintained by a rubber-bushed center support bearing, secured to a cross member of the frame. A typical center support bearing assembly is shown in figure 2-14. The standard bearing is prelubricated and sealed and requires no further lubrication; however, some support bearings on heavy-duty vehicles have lubrication fittings. The first indication of support bearing failure is excessive chassis vibration at low speed caused by the bearing turning with the shaft in the rubber support.

FINAL DRIVES

A final drive transmits the power delivered from the propeller shaft to the drive wheels or to sprockets equipped on tracklaying equipment. Because it is located in the rear axle housing, the final drive is usually identified as a part of the rear axle assembly. The final drive consists of two gears, called the ring gear and pinion. These are beveled gears, and they may be worm, spiral, spur, or hypoid, as shown in figure 2-15.

The function of the final drive is to change by 90 degrees the direction of the power transmitted through the propeller shaft to the driving axles. It also provides a fixed reduction between the speed of the propeller shaft and the axles driving the wheels. In passenger

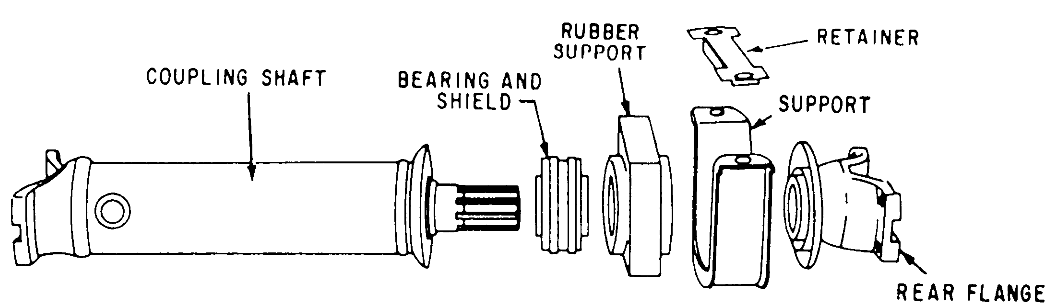

Figure 2-14.—Center support bearing.

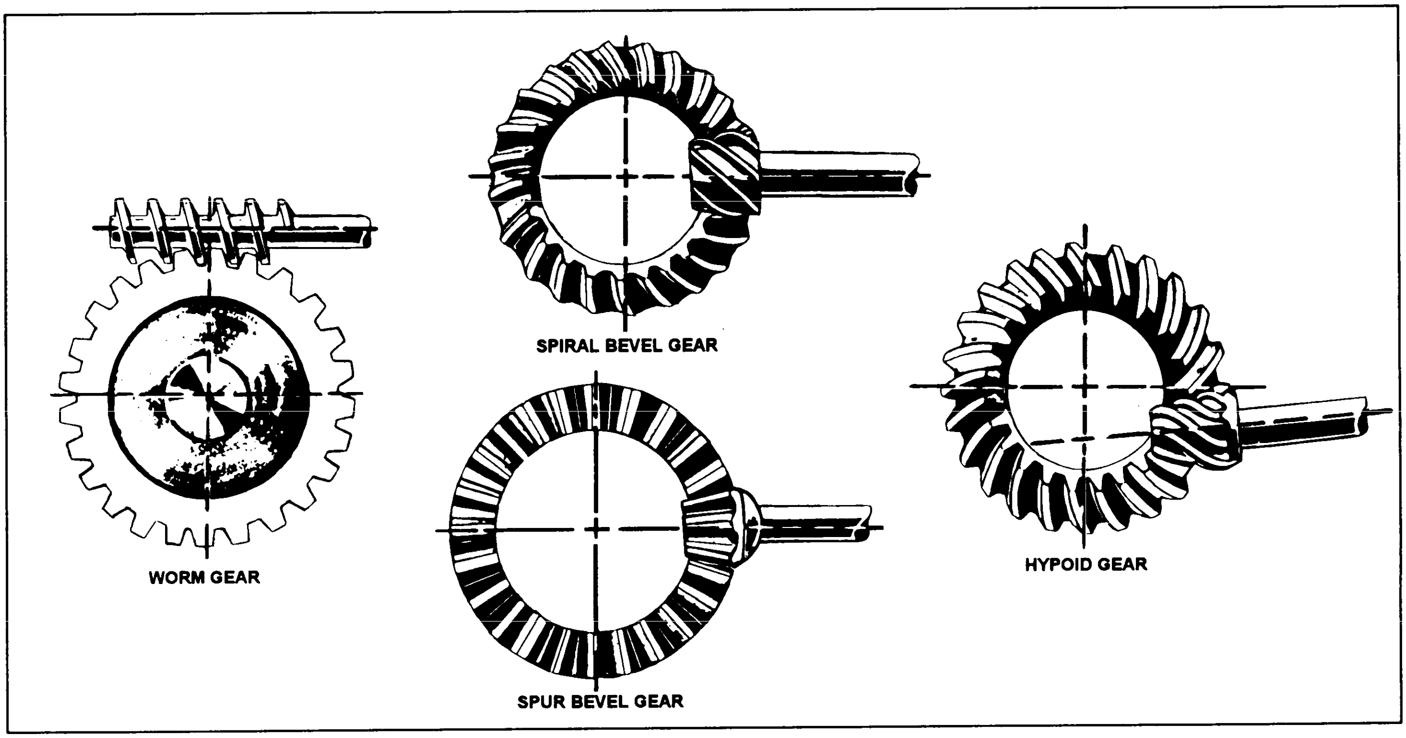

Figure 2-15.-Gears used in final drives.

cars, this reduction varies between 3 to 1 and 5 to 1. In trucks, it can vary from 5 to 1 to as much as 11 to 1.

The gear ratio of a final drive with bevel gears is frond by dividing the number of teeth on the driven or ring gear by the number of teeth on the pinion. In a worm gear final drive, the gear ratio is found by counting the number of revolutions of the worm gear for one revolution of the driven gear.

Most final drives are gear type. Hypoid differential gears permit a lower body design. They permit the bevel-driven pinion to be placed below the center of the ring gear, thereby lowering the propeller shaft, as shown in figure 2-15. Worm gears allow a larger speed reduction and are sometimes used on large trucks. Spiral bevel gears are similar to hypoid gears and are used in both passenger cars and trucks to replace spur gears that are too noisy.

DIFFERENTIALS

Another important unit in the power train is the differential, which is a type of final drive. As shown in figure 2-16, the differential is located between the axles and permits one axle shaft to turn at a different speed from that of the other. At the same time, the differential transmits power from the transmission/transfer case to both axle shafts. The variation in axle shaft speed is necessary when the vehicle turns a corner or travels over uneven ground. As a vehicle travels around a curve, the outer wheel must travel faster and further than the inner wheel. Without the differential, one rear wheel would be forced to skid when turns are made, resulting in excessive tire wear as well as making the vehicle more difficult to control.

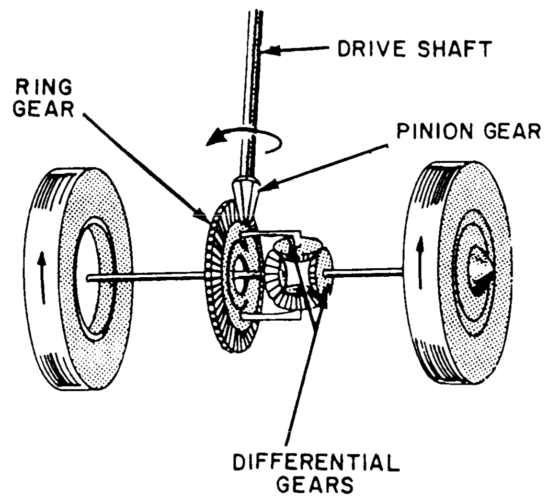

Figure 2-16.—Differential operation.

Some trucks have a differential lock to keep one wheel from spinning. This is a simple dog clutch, controlled manually or automatically. The differential lock locks one axle shaft to the differential case and bevel drive gear, forming a rigid connection between the two axle shafts that makes both wheels rotate at the same speed.

DRIVING AXLES

Axles are classified as either live or dead. The live axle is used to transmit power. The dead axle supports part of the vehicle weight but does not drive the wheels. The wheels rotate on the ends of the dead axle.

On rear wheel drive passenger cars, the front axle is a dead axle, and the rear axle is a live axle. In four-wheel drive vehicles, both front and rear axles are live axles, and in six-wheel drive vehicles, all three axles are live. Thee third axle, part of a bogie drive, is joined to the rearmost axle by a trunnion axle, as shown in figure 2-17. The trunnion axle is attached rigidly to the frame.

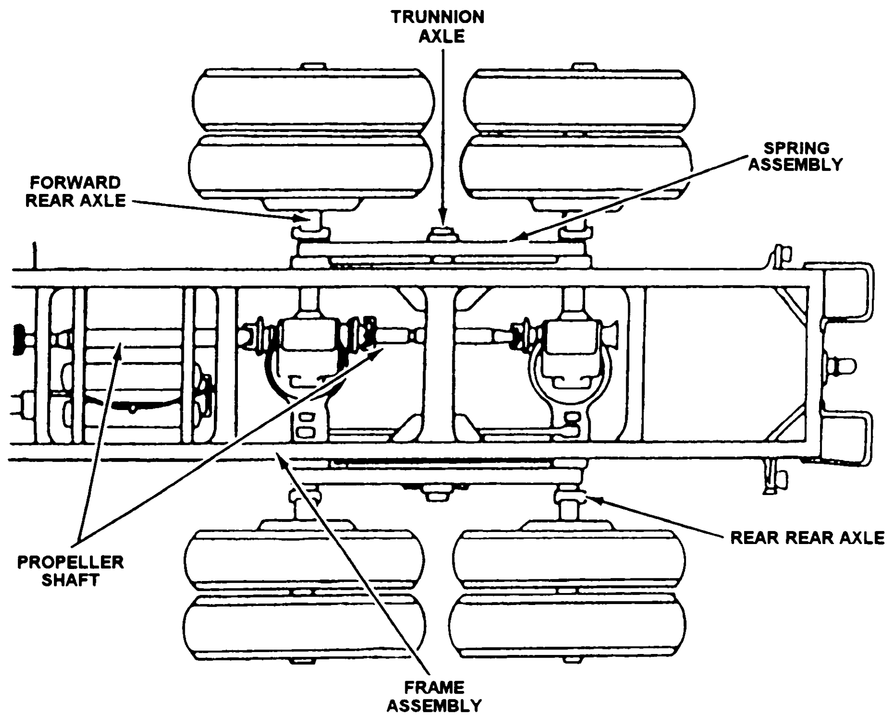

Figure 2-17.—Bogie drive.

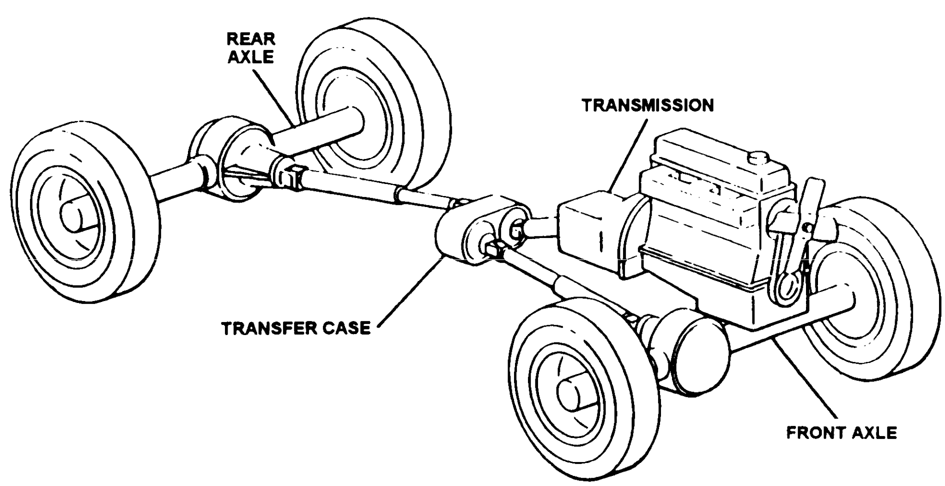

Figure 2-18.—Four-wheel drive transmission.

Its purpose is to help in distributing the load on the rear of the vehicle to the two live axles that it connects.

The three types of live axles that are used in automotive and construction equipment are as follows: semifloating, three-quarter floating, and full floating.

DRIVING WHEELS

Wheels attached to live axles are the driving wheels. Wheels attached to the outside of the driving wheels make up dual wheels. Dual wheels give more traction to the driving wheels and distribute the weight of the vehicle over more surface. Consider dual wheels as single wheels in describing vehicles.

The number of wheels is sometimes used to identify equipment; for example, a 4 by 2 could be a passenger car or a truck with four wheels, two of them driving. On a 4 by 4 (fig. 2-18), power is delivered to the transfer case where it is divided between the front and rear axle, allowing all four wheels to drive. A 6 by 4 truck with dual wheels in the rear is identified by six wheels, four of which drive. When a live axle is in front, the truck becomes a 6 by 6 (fig. 2-19), in which all six wheels drive.

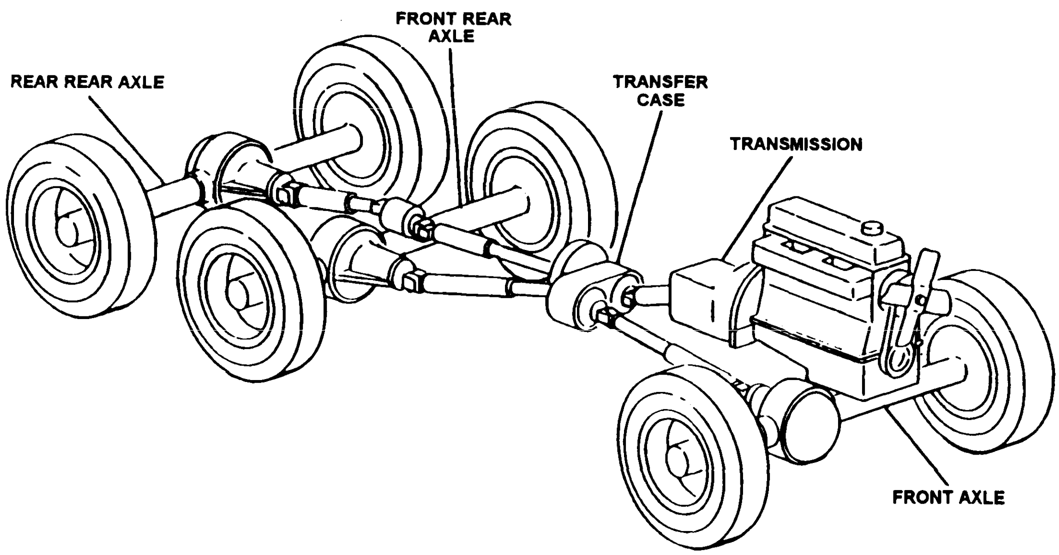

Figure 2-19.—Six-wheeled drive transmission.